A Study of the Consistency of Rate of Work

A STUDY OF THE CONSISTENCY OF RATE OF WORK

BY
CONSTANCE E. DOWD, Ph. D.

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A Study of the Consistency of Rate of Work

INTRODUCTION

This investigation was undertaken to determine the extent to which rate of work is an individual characteristic consistent for different performances. The question of rate of work has been recognized as an important one ever since the first reaction time experiments. It has been a vital issue in the group test field ever since the time when May and Terman[12] investigated the extent to which the length of time interval allowed for each test affected the relative position of the individuals tested.

A familiar criticism is that group tests are unfair to the slow but sure individual and that the quick type of person has an undue advantage. It is commonly believed that there is a quick type of person, that an individual that is fast at one kind of performance will be quick at another. Many an applicant for a position has been judged by his slow walk and has been rejected because of the belief that he would be slow in everything.

Before the many problems connected with quickness and intelligence can be solved it seems important to find out more than is now known about the nature of quickness or rate of work. We have attempted, therefore, to investigate one aspect of rate of work, that is, its consistency in different performances.

SECTION I

DISCUSSION OF PREVIOUS INVESTIGATIONS

The number of studies of correlations between tests is large, but there are few studies which consider the correlations between rate or speed in different tests. The first study that takes up the question of consistency of rate of work in different tests seems to be that of Wissler[20] in 1901. Wissler investigated the relationship between a large number of mental and physical tests. Among his tests there were five tests of "quickness", namely, a reaction time test, rate of perception, color naming, rate of movement, and an association test. The following table cited from Wissler's investigation gives the correlations between these tests of quickness:

	Cases	r
Reaction time and marking out A's	252	0.05
Reaction time and color naming	118	0.15
Reaction time and association	153	0.08
A's and color naming	159	0.21
Movement time and color naming	97	0.19
Movement time and reaction time	90	0.14

Wissler states that the rank of the individual in the whole series of time tests seems subject to chance. He adds that this conclusion is out of harmony with all general belief. Wissler's study was made before the recent discussion of the importance of reliability. He does not mention the reliability of his tests, hence we cannot tell how far the low correlations obtained are the result of differences in test content. The low correlations might have been caused in part by variation in performance that would have occurred on repetition of the same tests.

In 1924 Bernstein[1] investigated the possible existence of a speed factor with a quite different method. He used two types of tests, leisure tests and haste tests. The leisure tests were those in which ample time was allowed. They contained more difficult subject matter than did the haste tests. The haste tests had a time allowance too brief for any but the fastest subjects. Twenty tests were used, four of each of the following kind: Sentence Completion, Directions, Concomitants, Analogies, and Moral Classifications. The subjects were 158 school boys. The measure of slowness used was

score on leisure tests minus score on haste test, or L-H. Estimates of slowness were also obtained. These estimates showed a "negligible" correlation with the measure of slowness. The reliability of the slowness estimate was .42 for one group, and .55 for another. The average inter-correlation between leisure tests was .69 for one group and .71 for another, between haste tests .67 and .69, and between leisure and haste tests .66 and .73. The pooled tests had a correlation coefficient of —.40 with slowness estimate. Bernstein concluded that there was no clear evidence of the existence of a speed factor.

Clark,[3] in a study of "The Relation of Speed, Range and Level to Scores on Intelligence Tests", measured speed in two ways: (1) the speed at which pupils solved arithmetic problems, and (2) the speed at which they completed sentences. In the group tested for speed in arithmetic, Clark excluded all cases in which the accuracy of the performance was less than 80 per cent. The raw reliability correlation coefficient for arithmetical speed was .66, and the corrected coefficient .79. The reliability for speed on completion tests was found by correlating the median number of seconds spent on the odd numbered elements with the time spent on the even numbered elements. The raw reliability correlation coefficient for this test was .78, and the corrected coefficient was .88. The correlation between the two measures of speed, that is, speed in solving arithmetic problems, and speed in completing sentences, was .42. The corrected coefficient was .50. Clark was interested primarily in the relation between speed, range and level, and not in the relation between different measures of speed. Hence he was content with only two measures of speed and did not attempt to get a number of different measures. His correlation of .50 between these two fairly reliable measures of speed is of interest in the present connection and will be discussed later.

Hunsicker[9] measured rate on the same kind of tests that Clark used. Her subjects were divided into four groups and a reliability coefficient was found for each group. For rate in solving arithmetic problems the raw coefficients were .71, .76, .91, and .65, the corrected coefficients were .83, .86, .95, and .79. For rate in sentence completion the raw coefficients were .84, .61, .60, and .66, and the corrected coefficients were .91, .76, .75, and .80. Hunsicker's correlations between the two measures of rate are somewhat higher than Clark's. For the four different groups the raw coefficients were .71, .46, .56, .50, and the corrected coefficients were .81, .57, .67, .63.

Hunsicker states that these correlations indicate that "rate of work is an individual characteristic which shows up in performance". This conclusion is contrary to that drawn by Wissler as the result of his experiment. Wissler, however, used a greater variety of tests than Hunsicker and his correlation coefficients were not corrected for attenuation. The divergence in results in these two studies will be discussed later in connection with the present study.

The consistency of speed of decision is discussed by Bridges[2] and by Trow.[18] Bridges studied the nature of various decision types. He found that there is a type of subject who in simple situations is very quick and constant but who, when decisions are more difficult, becomes relatively slower and more inconstant. He states that decision times vary relatively with the kind of material. A person may be relatively quick in one kind of decision and relatively slow in another. Bridges' subjects were nineteen college students.

Trow's subjects were also college students, but a larger group, forty. For six different tests the correlations between speed of decision ranged from —.25 to .55.

Neither Bridges nor Trow state the reliability of their measures of speed of decision. These studies seem to agree, however, in finding that speed of decision is not consistent for different performances.

SECTION II

EXPERIMENTAL PROCEDURE

The subjects for this experiment were one hundred and sixty-five sixth grade children. This constituted an unselected sixth grade group, so far as such could be obtained. An Otis Advanced Examination had been given to all the sixth grade children in the city school system. The seven school rooms that were used for this experiment were chosen because their raw scores on the Otis Tests approximated a normal distribution. If a pupil was absent any day his records were omitted. One hundred and sixty-five is the final number of children that had the complete series of tests.

The tests were given in the same order to all of the subjects, with the same time intervals between tests. An hour a day was spent on each room for five days. The intelligence tests were not included in these five days but were given in additional periods. Each room was tested at the same period every day, with the exception of two occasions where the hour was changed from one o'clock to eleven o'clock.

Selection of Tests

As measures of rate of work, tests were selected that would not present great difficulty to the subjects. We tried to avoid the occurrence of errors by using tests that contained simple and familiar material.

It is obviously desirable to measure the amount of work done correctly so that the quality factor may be kept constant. Courtis[4] describes measurement of rate as follows: "The simplest measurement situation is when two individuals work at a uniform task and perform their work equally well. The difficulty factor and the quality factor are then constant, and difference in rate of performance, or amount done per unit of time, is the only record that need be considered in comparing the performances of the two individuals. Amount is the simplest of all quantities to measure. It is necessary only to adopt as a unit some division of amount—a word, or example, for instance—and by direct comparison, and a counting activity, to determine the total number of units accomplished in a given time. Time is easily measured." Courtis then describes the many difficulties that arise in the attempt to make quality constant.

In the tests used in this study the quality was approximately constant because of the simple nature of the tests. Three cancellation tests were used. In this type of test there is not room for much variation in quality—one cannot cancel a letter poorly or cancel it very well—if it is marked at all it is cancelled.

Two tests of hand movement were used. In these tests there was very little variation in quality as the performances were very simple and mechanical.

Whipple[19] makes a statement about time measurements that is applicable to the present situation. He says, "As a general rule, it may be said that time measurements become more significant and reliable in proportion as the task becomes more mechanical and less intellectual." This is doubtless true because it is easier to control the difficulty and quality factors in mechanical tasks than in intellectual tasks.

In the writing, reading and arithmetic tests there was more room for variation in quality. In each case, however, tests were arranged that would be easy for sixth grade pupils. The quality of the writing and reading tests is discussed in the section on Description of Tests. In the arithmetic tests the quality varied to some extent, but only absolutely correct responses were counted in the score. Hence, the measure of rate included only examples of the same quality.

It was, of course, impossible to determine the relative difficulty of the test content for different individuals. We have attempted to regulate the difficulty factor to some extent by using tests that were easy enough to avoid errors and by selecting tests that were of uniform difficulty throughout, that is, not graded for difficulty.

Description of Tests

The tests were all given as group tests. The time limit method was used throughout. The same examiner gave all of the tests.

The tests may be classified under five headings—Cancellation, Speed of Movement, Writing, Reading and Arithmetic.

Cancellation Tests

Three cancellation tests were used:

(1) Checking 6's according to Woodworth and Wells, (2) Underlining a's in pied type, Whipple's Manual No. 27008 and No.

27009, and (3) Cancellation of Symbols, Whipple's Manual No. 27010.

CANCELLATION OF 6'S:

Cancellation of "6's" was given for two periods of one minute each on three days, Monday, Tuesday and Friday. The subjects were told to work from left to right on each line and to put a check after each group of numbers that contained a "6". At the end of the first minute the examiner said "Stop, hold you pencils up," and then "Draw a ring around the last number that you have checked." After the examiner said "Ready—go," the subjects continued on the same page for another minute.

The score in this test was number of "6's" checked in six periods. If a "6" was omitted, the omission was noted, but not counted in the score. Very few omissions occurred. For the first period on the first day the average number of omissions was .69; for the second period the average was .91. For the last day the average number of omissions was .45 for the first period and .64 for the last.

CANCELLATION OF A'S:

Cancellation Test No. 27008, with pied type beginning "hplg" was given for three periods of one minute each on Monday. On Tuesday, Test No. 27009, beginning "zcyu" was given for three periods, on Wednesday, Test No. 27008 was given for two periods, on Thursday, Test No. 27009, and on Friday, Test No. 27008 was given for two periods. The subjects worked from left to right across the page as in reading. At the end of the first minute period in each case the children were told to stop, hold their pencils up, and then to draw a ring around the last "a" that had been underlined. After the examiner said "Ready—go" they started work on the next period.

The measure used in this test was number of "a's" underlined in six one-minute periods. When an "a" was omitted it was not counted in the score. The average number of omissions in the first period on the first day was 1.51; on the last day the average was 1.04.

CANCELLATION OF SYMBOLS:

Cancellation of symbols was given for one minute Tuesday, one minute Wednesday, one minute Thursday and one minute Friday. The children were told to cross out every triangle,

whether it was right side up, wrong side up, or sideways. In this test they were allowed to work the first line from left to right, the second line from right to left, and so on.

The score was the number of triangles cancelled in four one-minute periods. Omitted triangles were not scored. The average number omitted on the first page was 1.23, on the last page the average was 1.74.

Tests of Speed of Movement

WRITING "U's":

The examiner illustrated on the blackboard how "u's" should be written. See Figure 1. The subjects were told to write between lines on the lined pages, and not to spread the "u's" out too wide as only the peaks would count and it would take longer to make peaks far apart than close together. Three half-minute periods were given on Monday, and two half-minute periods on Wednesday. In scoring, every peak or upward stroke was counted as one. Variation in size of "u's" was not great as the lines on the page served to limit the height and subjects had been warned not to spread them laterally.

The measure of rate used was number of upward strokes made in four half-minute periods.

DRAWING GATES:

The subjects were instructed to draw little gates, that is, to make two perpendicular lines and a horizontal line across the two perpendicular lines. See Figure 2. The instructions were that the horizontal line must cross both of the perpendicular lines. This test was repeated for three half-minute periods on

FIGURE I

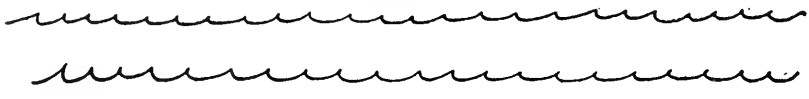
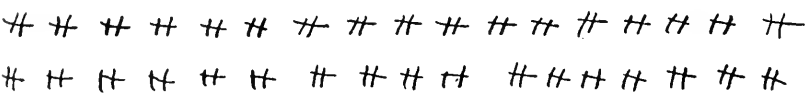


FIGURE II



Monday, two half-minute periods on Wednesday, and two half-minute periods on Friday.

When the horizontal line was drawn so carelessly as not to cross the perpendicular lines the gate was not counted in the score. The measure of rate used was total number of gates completed in six half-minute periods. The average number of incomplete gates in the first period was .01; in the second period the average was .12, and in the third period the average was .15. In the last period on the last day the average was .17.

Writing Tests

WRITING A SENTENCE:

The subjects were instructed to write "The quick brown fox jumps over the lazy dog" until they knew the sentence without looking at the copy. They were then told to start at the signal "Go" and to write the sentence as many times as they could before the examiner said "Stop" at the end of a two-minute period. After a rest they went on for a second two-minute period. Three days later the test was repeated for two more two-minute periods.

WRITING NUMBERS:

Another writing test was given on Thursday. The subjects wrote "one two three four five six seven eight nine ten" for four half-minute periods.

The measure of rate was number of letters written in four half-minute periods. The total number of letters written was counted with no penalty for omissions. In the first period, seven subjects omitted one letter, and five subjects omitted a whole word. One hundred and fifty-three subjects had no omissions.

Originally we planned to score for quality as well as speed and to correct the measure of speed according to Gates' formula,

$$\text{Speed} = \left(\frac{\text{Combined Score}}{\text{Quality}}\right)^3$$

Accordingly a number of tests were scored for quality. It was found that the specimens of one individual rarely varied for more than one point on the Thorndike Writing Scale, and that the variation was small between the quality of different individuals. It is admitted that an individual might lessen his quality to increase his speed. Since, however, we found a reliable measure by counting the number of letters written without taking

account of quality it seemed reasonable to consider number of letters written as a measure of rate. Our standard for quality was merely the presence of every letter and the legibility of every word. The reliability of the test is discussed in the next section.

Reading Tests

A series of four tests were devised from a geography book, "Journeys in Distant Lands" by Barrows and Parker. In this book the reading has been so arranged as to be simple enough for fourth grade children. It seemed, therefore, that it would present no great difficulty to sixth grade pupils. Instructions were given as follows: "Write your names on the back of these reading sheets and do not turn them over until I say 'Ready—go'. I want to find out how to divide this long sheet into pages according to the rate at which sixth grade boys and girls read. You read along at your own rate and when I say 'Mark', draw a ring around the word that you are reading to show where your page would end. Some of you will have long pages and some will have short pages. You will all have time to finish the sheet. Be sure that you understand what you are reading as there will be questions about it at the end. Take your pencils in your hands and remember to draw the ring when I say 'Mark'." The examiner said "Mark" every half minute. Four half-minute periods were given on Monday, six periods on Tuesday, four periods on Wednesday, and four periods on Friday. If any children had not finished at the end of these periods they were allowed to go on and finish in their own time. After they had finished reading they were told to answer the questions and to fill in the completions at the end.

The measure of rate of reading was total number of words read in the first two periods, for four days.

There was, of course, no chance to count errors in reading. The errors in filling in the completions and in answering the questions at the end were few. Since the passages were chosen from a fourth grade book, it is reasonable to expect that all sixth grade pupils could read them without making serious errors. The average number of errors in the completions on the first test was .02.

Arithmetic Tests

The Monroe Standardized General Survey Arithmetic Scales, Form 1, Form 2 and Form 3 were given on three separate days.

These tests were chosen because the examples were very simple, and there were a number of examples of the same kind not graded for difficulty. The tests were given in order as they appeared on the blank: (1) addition, time limit 50 seconds, (2) subtraction, time limit 60 seconds, (3) multiplication, time limit 60 seconds, and (4) division, time limit 60 seconds.

The measure of rate was the number of examples worked correctly on the three forms of the test. There were very few errors in Addition, Subtraction and Division. In Multiplication there were an appreciably greater number. The average number of errors for the first day were .35 in Addition, .56 in Subtraction, 3.43 in Multiplication and .77 in Division.

Otis Advanced Examination

The Otis Advanced Examination was given before the rate tests. This test was chosen because it is well adapted to sixth grade children and is one of the most widely used of the group tests.

The scores in the present study ranged from 35 to 150, with a mean of 91.86 and a standard deviation of 24.19. In 1924 the writer had access to the results of the Otis Advanced Examination that was given to all the sixth grades in a whole city school system. For 3705 cases the range in score was 13-164 with a mean of 84.40 and a standard deviation of 23.60. An unselected sample of 1236 cases drawn from these 3705 cases showed a range from 13 to 156, a mean of 83.39 and standard deviation of 24.02.

The present group of 165 cases approximates what we would expect of an unselected sample with the exception that the lower end of the distribution seems to be cut off. The original group of 250 cases included some children with scores lower than 35. It was impossible to predict that the duller children would tend to be absent more than the brighter children but this seems to have been the case.

In order to find the reliability of this intelligence test for this group and as a check on the measure of intelligence the alternate form of the Otis Advanced Examination was given. The correlation between the two forms was .83 with a probable error of .02. (Otis[14] gives as the reliability for the test .88.)

The results of correlation between the rate tests and combined Otis scores were practically the same as those between rate tests and the first Otis Test score.

Tests That Were Omitted Because of Low Reliability

DOT MAKING TEST, originally included in tests of hand movement:

Healy Test Blanks No. 19235 were used for this test. The subjects were instructed to put one dot in each square, and thus fill as many squares as they could before the examiner said "Stop." They were allowed to work the first line from left to right, second line right to left, and so on for fifteen seconds. They were then told to hold their pencils up and after that they were told to draw a ring around the last dot that had been made. At a second signal they went on for fifteen seconds more. Subjects were told that only one dot in a square would count. Since several subjects finished the page before the end of the second period, only the first period on each page could be used. The correlation between scores in these periods was .535.

DICTATION:

This test was given with a view to testing ability to distinguish words that were spoken very quickly. Words from Thorndike's Word List were read at a very fast rate, so that the children could not write all the words that were read. Words were chosen from five hundred simplest words on Thorndike's list. Four different rates were used. At the first rate one word was read every four seconds. At the second rate one word was read every two seconds. At the third rate one word was read every one and a half seconds. At the fourth rate one word was read every one and a quarter seconds. Fifteen words were read in each set and a second set of fifteen at the fastest rate. In order to insure a uniform rate of reading a metronome was set at the desired speed and the words were read in time to the metronome beats.

The correct words in the two sets that were read at the fastest rate were counted for each day. The correlation between the first two days and last two days was .706. A combination of first, fourth, fifth and eighth periods was correlated with second, third, sixth and seventh periods. This was correlated for two schools (81 cases) and found to be .708. The correlation between the first and fourth days and second and third days was .693.

COMPLETION TESTS, originally included under Reading Tests:

The I.E.R. Completions 1 to 44 were used. These are the two levels of the test that Hunsicker used for the "no difficulty

level." Before these were given a page of completions collected from the Trabue Scales was given as a practice exercise. The I.E.R. Completion Sheet 1 through 24 was given with a time limit of one minute. The sheets were passed out wrong side up. Names were written on the back. The pupils were told to start work as soon as they turned the page over. The practice sheet used on the previous day had been made up in the same form as the I.E.R. Tests so that no confusion would arise in connection with reading the directions or writing names in the space for the name at the top of the sheet. The next day Completions 25 through 44 were given in two one-minute periods. After this, another set of completions devised from the Trabue Scales and the National Intelligence Test was given for two one-minute perods. After two weeks the I.E.R. Tests were given again.

The reliability of this test was found by correlating the first sheet (one minute) with the second Sheet (two minutes) r= .672. The correlation between the first minute on the first sheet and the first minute of the second sheet was .437.

The first sheet was repeated two weeks later and the coefficient was .738 for one hundred and fifty-seven cases. The second sheet had a self-correlation of .700 when given for one minute and .519 when given for two minutes.

PUZZLE TEST:

The Michigan Puzzle Test Form 1, Test 1, was given according to the regular instructions for this test. Time was called every half-minute. Since there is no alternate form of this test, only one form could be used and reliability was obtained by correlating the first and fourth periods with the second and third periods on the same test. The coefficient of correlation was .690.

ARITHMETIC PROBLEMS:

I.E.R. Arithmetic Problems 1 through 20 were given for two one-minute periods on Wednesday, and Problems 21 through 40 were given for two one-minute periods on Thursday. As some subjects finished the tests before the end of the second period the first two periods were used in scoring. The correlation of the first two periods was .631.*

*The I.E.R. Tests were the property of the Institute of Educational Research. The writer is indebted to Professor Thorndike for permission to use these tests.

SECTION III

RELIABILITY OF THE TESTS

In order to determine how far rate work is an individual characteristic consistent for different performances it is necessary first of all to get a measure of rate that has high reliability for each performance. If a subject's rate of work should vary from time to time on the same test no one performance on that test would be a true measure of his rate of work.

Otis[13] says that two tests cannot correlate with each other any higher than they correlate with themselves. He states that "if each of two tests has a reliability coefficient of .80 these two tests cannot correlate with one another higher than .80".

In this study certain tests that were given showed a low reliability. It was thought best to throw out these tests since they did not offer any consistent measure of rate. The tests eliminated because of low reliability are discussed at the end of the section on Description of Tests.

The reliability for all of the tests that were used was above .90. When four periods were given in any test the reliability was found in the customary manner by correlating the sum of the scores of the first and fourth periods with the sum of the scores of the second and third periods.

Where a test was repeated six times the reliability was found by correlating the sum of the first, fourth and sixth periods with the sum of the second, third and fifth periods.

The coefficients of correlation between the two halves of each test are shown on Table I. In order to determine the reliability of the whole of any test the coefficient of correlation between the halves was corrected by the Spearman-Brown prophecy formula:[5]

$$r = \frac{Nr}{1-(N-1)\,r} \times$$

These reliabilities are also shown on Table I.

The test that had the lowest reliability was Drawing Gates, which had a reliability coefficient of .905.

The test that had the highest reliability was cancellation of a's, .970. Writing u's had a reliability of .969.

TABLE I

RELIABILITY OF THE TESTS

	r. For two halves of the Test	P.E.	r. Corrected by Spearman-Brown Prophecy Formula	P.E.
6's	.937	.01	.968	.01
A's	.942	.01	.970	.01
Symbols	.843	.01	.915	.01
U's	.940	.01	.969	.01
Gates	.827	.01	.905	.01
Sentence	.877	.01	.934	.01
Numbers	.869	.01	.929	.01
Reading	.832	.02	.908	.01
Arithmetic	.884	.01	.938	.01
Otis Advanced Examination— (r. for two forms of the Test.)			.832	.02

McCall[11] gives the reliability coefficients for five standard educational tests as .55, .7, .75, .8 and .9. He says that a score will be sufficiently reliable for most purposes even though the tests self-correlation is as low as .55, but that for important judgments concerning individual pupils, the self-correlation should be above .9.

In order to judge the consistency of any trait as measured in different tests, it seemed that the self-correlation of each test used should conform to the highest standard of reliability. Hence, all of the tests that were used had reliabilities above .90.

SECTION IV

RESULTS

The inter-correlations between the nine rate tests are shown on Tables II and III. All of the correlations were positive. The lowest coefficient was .139 between Reading and Arithmetic. When this coefficient is corrected for attenuation the maximum theoretical correlation is .151. The highest coefficient was that between writing a sentence and writing numbers, .810 or, when corrected for attenuation, .870.

The difference between the highest and lowest coefficient is large. It is as large as the difference between the coefficients found by Wissler and those found by Hunsicker. The lowest coefficient found by Wissler was between reaction time and marking out A's .08 (not corrected for attenuation). The highest found by Hunsicker was .81 (corrected for attenuation).

Woodrow[21] in discussing the theory of mental make-up says that the correlations first obtained seemed to support the non-focal theory. He says "They were so low in most cases as to suggest little or no correspondence between any two mental abilities. Thus, Wissler,

TABLE II

INTERCORRELATIONS BETWEEN RATE TESTS

(Raw Coefficients)

	6's	A's	Symbols	U's	Gates	Sentence	Numbers	Reading	Arithmetic
6's		.559	.592	.241	.469	.409	.420	.221	.418
A's	.559		.579	.342	.348	.312	.320	.169	.163
Symbols ..	.592	.579		.447	.465	.370	.418	.261	.249
U's	.241	.342	.447		.526	.504	.557	.337	.130
Gates	.469	.348	.465	.526		.504	.657	.225	.327
Sentence ..	.409	.312	.370	.504	.504		.810	.302	.351
Numbers ..	.420	.320	.418	.557	.657	.810		.370	.345
Reading ...	.221	.169	.261	.337	.225	.302	.370		.139
Arithmetic.	.418	.163	.249	.130	.327	.351	.345	.139	

TABLE III

INTERRELATIONS BETWEEN RATE TESTS

(Coefficients corrected for attenuation)

	6's	A's	Symbols	U's	Gates	Sentence	Numbers	Reading	Arithmetic
6's		.576	.629	.248	.498	.430	.442	.235	.440
A's	.576		.615	.352	.374	.328	.336	.179	.171
Symbols ..	.629	.615		.475	.510	.402	.454	.286	.267
U's	.248	.352	.475		.559	.530	.586	.358	.136
Gates	.498	.374	.510	.559		.547	.714	.247	.355
Sentence ..	.430	.328	.402	.530	.547		.870	.328	.377
Numbers ..	.442	.336	.454	.586	.714	.870		.402	.370
Reading ..	.235	.179	.286	.358	.247	.328	.402		.151
Arithmetic.	.440	.171	.267	.136	.355	.377	.370	.151	

PROBABLE ERRORS

r.	P.E.
.00	.055
.10	.055
.20	.053
.30	.050
.40	.046
.50	.041
.60	.035
.70	.028
.75	.024
.80	.020
.85	.015
.90	.010

who published the results of the tests given for many years to the freshmen of Columbia University, came to the conclusion that although the markings of students in college classes correlate with each other to a considerable degree, they do not bear out the mental tests, nor do the mental tests show much correlation with each other.

"To a considerable extent the correlations found at first were low because of inaccurate measurements and inadequate statistical methods."

Woodrow was discussing tests of mental ability and not speed tests. His discussion is of interest, however, in the present connection because Wissler's tests of quickness showed the same low correlations that the mental tests showed. These low correlations have been thought to be due to inaccurate measurements and inadequate statistical methods that were used some years ago.

It is of particular interest that some of the correlations found in the present study where the reliabilities of the tests were above .90, should be almost as low as those found at the very start of the testing movement by Wissler.

It seems difficult at first glance to reconcile these low correlations with some of the very high correlations found on Table II. Upon investigation, however, it appears that the high correlations tend to be between tests of which the content is obviously similar. The highest correlation of .870 is between writing a sentence and writing numbers. This is almost as high as the correlation of the two independent series that were used to find the reliability of either test. It suggests that rate in writing any familiar words is just as consistent as rate in writing the same words.

Other high correlations are found between the writing tests and hand movement tests. Here the inter-correlations are all above .50. The cancellation tests have inter-correlations above .50. Obviously here again the high correlations are between tests that are similar in content.

In considering the high correlations between different measures of rate found by Hunsicker, the kind of test used must be considered. Hunsicker's correlation between rate in Arithmetic and rate in Completion was .81 for one group, .57 for another, .67 for a third and .63 for a fourth group. For measures of rate she used tests at the "no difficulty" level. If these tests presented no difficulty to the subjects it would seem that what they measured was time required to read the questions or sentences, and time required to write the answers. This reduces the two tests to fairly similar prcoesses and the situation becomes somewhat analogous to that in which tests of similar material are used, as for instance, the writing tests, or cancellation tests of the present study.

It seems, therefore, that the results of Wissler and Hunsicker might be reconciled. In similar performances rate does seem to be a characteristic that shows consistency to an appreciable extent. In dissimilar performances, however, rate does not seem to be consistent.

The correlation of .15 between reading and arithmetic in the present study seems surprising in comparison with that found by Clark between speed in completion tests and speed in arithmetic. Clark's correlation corrected for attenuation was .50.

When we examine the tests used, however, it becomes apparent that the tests used by Clark were far more similar than the tests used in the present study. The two series, arithmetic problems and sentence completion, that were used by Clark both involved reading sentences, and writing answers. In the present study the measure of rate of reading involved no writing at all, and the measure of arithmetic rate involved no reading of words. The directions were given by the examiner and the subjects dealt entirely with figures.

The rate tests used in the present investigation offer more different kinds of test content than do rate tests of any of these previous studies with the exception of Bernstein's experiment. Bernstein's data, as has been noted above, were interpreted to show the nonexistence of a speed factor.

According to Rugg's[16] classification a coefficient of less than .15 to .20 is "negligible", and "present but low" ranges from .15 or .20 to .35 or .40. Four of the thirty-six coefficients on Table II are negligible, and sixteen are present but low.

It seems, therefore, that some of the coefficients found in the present study are low enough to indicate that rate is not to any appreciable extent an individual characteristic consistent for different performances. To be sure, the different rate tests used in this study correlate with each other more than they do with the intelligence tests. They correlate with each other more than tests chosen at random would be expected to correlate. Many of the correlations were so low, however, that the mere fact of their being positive cannot be interpreted as an indication of appreciable consistency.

The amount of community between tests and the extent to which one might predict rate on one test from rate on another cannot be found directly by looking at the correlation coefficient. The lack of relationship or standard error of estimate must be taken into account. The coefficient of correlation measures the presence of relationship and the lack of relationship between two variables is measured by the coefficient of alienation $1-r^2$ as explained by Kelley.[10] The coefficient of alienation for the present tests are shown on table XI.

Hull[8] gives a convenient measure of what he terms "Efficiency of Prognosis" that shows clearly the lack of relationship between

variables. Thus in order to have fifty per cent efficiency of prognosis two tests must correlate .866. Of the tests used on the present study only two correlate this highly, namely, Writing a Sentence and Writing Numbers.

It appears that although there is a certain degree of relationship between these tests of rate of work in different performances it is not high enough to serve as a reliable basis for prediction.

TABLE XI

r.	Coefficient of Alienation $\sqrt{1-r^2}$	Efficiency of Prognosis $1-\sqrt{1-r^2}$
.00	1.000	.000
.05	.999	.001
.10	.995	.005
.15	.989	.011
.20	.980	.020
.25	.968	.032
.30	.954	.046
.35	.937	.063
.40	.917	.083
.45	.893	.107
.50	.866	.134
.55	.835	.165
.60	.800	.200
.65	.760	.240
.70	.714	.286
.75	.661	.339
.80	.600	.400
.85	.527	.473
.90	.436	.564
.95	.312	.688
.97	.243	.757
.99	.141	.859

In order to investigate further the possible existence of a speed factor various combinations of tests were made and the correlations computed between the compounds.

The scores on each test were reduced according to the method suggested by Hull[7]. A cancellation total was found by combining the three cancellation tests. A hand movement total was made up of the two tests of hand movement, Writing u's and Drawing Gates. A writing total was made of the two writing tests.

The correlations between these combinations of similar tests are shown on Table IV.

On the whole, combining the tests seems to raise the correlations. The average correlation between a cancellation test and a hand movement test is .385. The correlation between the combined cancellation tests and combined hand movement tests is .505. This is a greater rise than is obtained by correcting the coefficients of the separate tests for attenuation, as the average correlation between a cancellation test and a hand movement test when the coefficients are corrected for attenuation is .433.

The correlations of these compounds with Reading and Arithmetic are, on the whole, slightly higher than were the correlations of separate tests with reading and arithmetic.

TABLE IV

CORRELATIONS BETWEEN COMBINATIONS

(Raw Coefficients)

	Cancellation	Hand Movement	Writing	Reading	Arithmetic
Cancellation Tests		.505	.465	.266	.331
Hand Movement Tests	.505		.665	.336	.231
Writing Tests	.465	.665		.340	.370
Reading	.266	.336	.340		.139
Arithmetic	.331	.231	.370	.139	

PROBABLE ERRORS

r.	P.E.
.00	.055
.10	.055
.20	.053
.30	.050
.40	.046
.50	.041
.60	.035
.70	.028
.75	.024
.80	.020
.85	.015
.90	.010

TABLE V

CORRELATIONS OF COMBINED TESTS

(Coefficients Corrected for Attenuation)

	Cancellation	Hand Movement	Writing	Reading	Arithmetic
Cancellation Tests		.526	.487	.283	.347
Hand Movement Tests	.526		.696	.360	.244
Writing Tests	.487	.696		.365	.390
Reading	.283	.360	.365		.151
Arithmetic	.347	.244	.390	.151	

Further combinations were made of all cancellation and hand movement tests. The effect was to raise slightly the general run of the coefficients. See Table VI.

On the whole we may say that by combining the rate tests we tended to get a measure of rate that is more consistent for different performances than are the measures on the separate tests. Since, however, even the combinations produce some coefficients well below .50 it still appears that rate as measured by combinations of these tests is not to any great extent consistent for different performances.

Various other combinations were made between tests of dissimilar material. See Table VII. The two separate tests that showed the very lowest correlation, Cancellation of 6's and Writing u's were combined and the compound correlated with the compound of the two separate tests that showed the next lowest correlation, Cancellation of a's and Arithmetic. The correlation was found to be .573.

The highest correlation between any compounds .639 between Reading, Writing and Arithmetic, and Cancellation and Hand Movement Total is not high enough for reliable prognosis.

TABLE VI

CORRELATIONS OF COMBINED TESTS

(Raw Coefficients)

	Writing	Reading	Arithmetic
Cancellation and Hand Movement Tests.....	.634	.335	.326

	Cancellation	Reading	Arithmetic
Hand Movement and Writing Tests	.536	.369	.314

TABLE VI—A

CORRELATION OF COMBINED TESTS

(Coefficients Corrected for Attenuation)

Cancellation and	Writing	Reading	Arithmetic
Hand Movement Tests	.660	.356	.341
	Cancellation	Reading	Arithmetic
Writing Tests	.553	.393	.328

TABLE VII

CORRELATIONS BETWEEN COMPOUNDS OF TESTS OF DIFFERENT MATERIAL

(Raw Coefficients)

	r.	P.E.
Reading and Arithmetic with Cancellation	.408	.04
Reading and Arithmetic with Hand Movement	.387	.05
Reading and Arithmetic with Writing	.500	.04
Reading and Arithmetic with 6's and u's.....	.457	.04
Reading and Writing with Cancellation	.485	.04
Reading and Writing with Hand Movement	.658	.04
Reading and Writing with Arithmetic	.337	.05
Reading, Writing and Arithmetic with Cancellation and Hand Movement	.639	.04
Cancellation of 6's and Writing u's with Cancellation of a's and Arithmetic.....	.573	.04

The coefficients were rearranged in an attempt to find whether they could be grouped in a hierarchy. It was impossible to find any arrangement that would conform to the criterion for a hierarchy. Although there is no hierarchy in these coefficients there are elements of community between almost any two tests.

If there is a general speed factor it cannot have a great deal to do with performance on different tests. Whether the differences in rate were due to difference in mental make-up of the subjects or to difference in set toward test content we are not prepared to say.

In the light of the data of this study we would say that if the two tests of rate of work were of similar performances the correlation would tend to be moderately high. If the tests were of absolutely similar performances the correlations might be very high. If the tests were of different performances, however, the correlations would probably be low.

Whether the inconsistency in rate is due to an individual's mental make-up or to differences in set toward content, we are not prepared to say.

SECTION V

RESULTS OF CORRELATIONS WITH INTELLIGENCE TEST SCORE

The results of the correlations with the Otis Advanced Examination are shown on Table VIII.

It has been shown in the previous section that rate of work as measured by nine different tests is not to any appreciable extent an individual characteristic consistent for different performances. It would seem ridiculous, therefore, to try to prove that the relations shown on Table VIII are in any sense an index of the true relation between rate of work and intelligence.

In order to discover the true relationship between rate of work and intelligence it would be necessary to find the correlation between rate in every possible kind of performance and intelligence. In order to be able to predict rate of work from intelligence, or intelligence from rate of work, we should have a high correlation between rate of work in the particular performance under discussion and intelligence.

It is of interest however, that the correlations in the present study are much lower than most correlations reported by previous investigators. Clark[3] found a mean correlation of .495 between his three measures of intelligence and two measures of speed.

Peak and Boring[15] state that they have concluded that "speed of reaction is an important and probably the most important factor

TABLE VIII

CORRELATIONS BETWEEN SCORE ON INTELLIGENCE TEST AND SCORE ON RATE TESTS

Rate Tests.	r. Raw Coefficient	P.E.	r. Corrected for Attenuation	P.E.
6's	.032	.06	.035	.06
A's	—.084	.06	—.094	.06
Symbols	.078	.06	.090	.06
U's	.100	.06	.111	.05
Gates	—.066	.06	—.076	.06
Sentence	—.018	.06	—.020	.06
Numbers	.004	.06	.004	.06
Reading	.298	.05	.346	.05
Arithmetic	.118	.05	.135	.05

TABLE IX

CORRELATIONS BETWEEN SCORE ON INTELLIGENCE TEST AND COMBINED SCORES

(Raw Coefficients)

	r.	P.E.
Otis Advanced Examination with Combined Cancellation Tests	.016	.06
Otis Advanced Examination with Hand Movement Tests	.003	.06
Otis Advanced Examination with Combined Writing Tests	.004	.06
Otis Advanced Examination with Combined Hand Movement and Writing Tests	.008	.06
Otis Advanced Examination with Grand Total	.089	.06

TABLE IX—A

CORRELATIONS BETWEEN SCORES ON INTELLIGENCE TESTS AND COMBINED RATE TESTS

(Coefficients Corrected for Attenuation)

	r.	P.E.
Otis Advanced Examination and Combined Cancellation Tests	.017	.06
Otis Advanced Examination and Hand Movement Tests	.037	.06
Otis Advanced Examination and Combined Writing Tests	.004	.06
Otis Advanced Examination and Grand Total of Rate Tests	.099	.06

in individual differences in the intelligent act." They found correlations of .90 between reaction time and scores of both Army Alpha and the Otis Self Administering Tests. Speed as measured by rate of performance on Alpha correlated .90 with scores of both Alpha and Otis. Speed as measured by the Otis test correlated 1.00 with scores on either test. Since, however, this experiment was made on only five subjects these correlations mean very little, and it must be noted that speed in this case was measured on the same tests as intelligence.

The measures of speed that Clark used are probably much more like the measures of intelligence in an intelligence test than were the measures of speed in the present study. For instance, his measure of speed in solving arithmetic problems consisted in reading a question and writing an answer. Most of the intelligence group tests have

a page of just this kind of material. His completion speed consisted in reading an incomplete sentence and writing in the omitted word. None of the tests used in the present study included questions to be read and answered. Our reading tests were straight reading of several paragraphs. Our writing tests were mere mechanical writing with practically no thought involved. Our cancellation and hand movement tests certainly had little in common with any of the material in an intelligence test.

The test that showed the highest correlation with score on intelligence test was Reading r=.346 (corrected for attenuation). This test would be judged to have more in common with the Otis Advanced Examination than would any of the other tests.

Partial correlations were found between various rate tests with intelligence constant. See Table X. There was very little difference in relationship between rate tests when intelligence was made constant.

TABLE X

PARTIAL CORRELATIONS

	r.
Reading with Arithmetic, with Intelligence constant.....	.111
Reading with Cancellation, with Intelligence constant.....	.279
Reading and Arithmetic with Cancellation, with Intelligence constant	.421
Reading with Intelligence, with Age constant.....	.230
Cancellation with Hand Movement and Writing Total, with Age constant	.522

The correlations between age and the rate tests were found to be low or negligible. Hence, when age is partialled out there is no great change in relationship between the rate tests.

Thorndike[17] has said that score on a standard instrument for measuring intelligence is in a degree determined by one's speed of reacting, one's range of information, and one's general power or level. In Clark's study the interrelations between the three factors were found to be high. Clark, however, only investigated the relation between intelligence and two measures of speed.

Thorndike's statement undoubtedly holds true, if we assume it to mean that speed on a similar performance or the same performance determines score on intelligence test. If however speed is not an individual characteristic consistent for different performances the statement cannot be interpreted to mean that speed in general is correlated with intelligence as measured by standard tests.

CONCLUSION

When the question of whether speed is a general trait is tried out with suitable material the result is that we get a series of correlations ranging from .136 to .870 with the preponderance of coefficients at the low end of the range. The only correlations that are high are between tests in which the content is similar.

In this study the material was suitable for trying such an experiment in that the reliability of each measure of speed was very high, above .90, and the measures were free from confusion with different kinds of measures. The score was amount of work done within a given time limit, accuracy and quality being kept practically constant and difficulty being uniform throughout each test and rather slight for sixth grade subjects.

It cannot be objected that the low correlations were due to low reliability so it must be a fact that a person that is speedy in one thing has only a slight tendency to be speedy in another. High correlations are more likely to be due to similarity of material than to a general speed factor. A try-out by the devise of hierarchy failed to show evidence of a general speed factor.

We venture the conclusion therefore, that there is no general speed factor or, in other words, that an individual cannot be rated as so-and-so rapid in a general sense. If there is a speed factor it must be of slight force.

It is also worth particular attention that speed as measured by these tests has little to do with score on intelligence test.

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